Wisconsin Department of Natural Resources

COMPARING GLOBAL POSITIONING SYSTEM (GPS) TOOLS

Selecting the right tool for the job!

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This is a companion document to DNR's ***Locational Data Standards***.
This document and DNR's ***Global Positioning System (GPS) Accuracy Report*** are both available for downloading via the Internet:
http://www.dnr.state.wi.us/org/at/et/geo/location/gps_info.html

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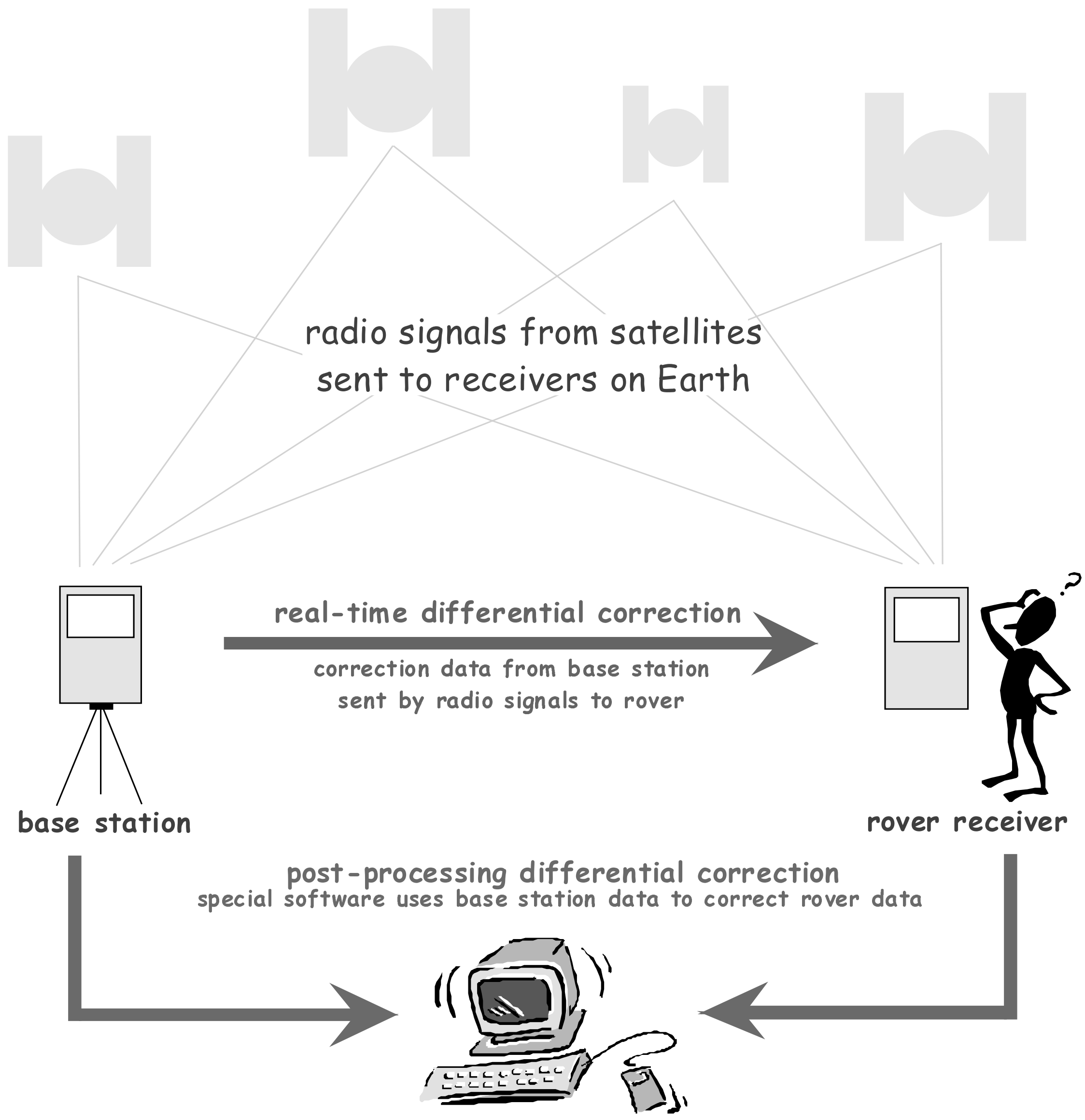
I. BACKGROUND INFORMATION

1. **WHAT IS GPS?**

Global Positioning System (GPS) is a constellation of 24 satellites, each of which orbits Earth once every twelve hours. The U.S. Department of Defense (DOD) operates and maintains these GPS satellites. Each satellite contains a high precision atomic clock and several transmitters that constantly send radio signals back to Earth. These signals communicate the satellite's unique identification code, health, and position in space.



GPS "rover" and "base station" units in the field receive these satellite signals and use them to calculate positions. All GPS receivers collect the locations of real-world features (represented as points, lines or areas), and some can also store descriptive data, or attributes, about these features.

2. ABOUT THIS DOCUMENT

The Enterprise Data Management Section and GIS Mapping and Analysis Services Section have developed this guidance document to help DNR program staff who are considering the use of GPS tools to collect feature location data. It presents several major issues and characteristics for you to consider when comparing, and ultimately selecting, an appropriate GPS tool. We will review the contents of this document regularly, and revise them as necessary, to reflect changing DNR business needs, new technology, and the development of related standards and guidance. While this document does not endorse any particular GPS product or manufacturer, it does reference external sources of GPS information, where appropriate. The most current version of this document is also posted on the Intranet: http://intranet.dnr.state.wi.us/int/at/et/geo/location/location_index.html.

3. SELECTING THE RIGHT DATA COLLECTION TOOL FOR THE JOB

A DNR program intending to collect the locations of real-world features must choose a tool capable of capturing data that adequately support its business needs. The program's resources (e.g., staff, hardware, software) must also be sufficient to support the use and maintenance of the selected data collection tool. Therefore, choosing the right data collection tool for a specific project requires serious consideration of the following:

- Anticipated uses of the feature location and attribute data to be collected.
- Program data accuracy requirements for the data to be collected.
- Available program resources to support data collection and processing activities.
- Type, number, and other characteristics of features to be located.
- Characteristics (e.g., rural vs. urban, remote vs. nearby) of the data collection site.
- Need to identify and use existing feature location or attribute data.
- Need to identify and use existing data collection procedures or standards.
- Type of feature attribute data to be collected
- How the features to be located will be represented (i.e., as points, lines, or areas).

4. CHARACTERISTICS OF GPS TOOLS AND DATA

GPS data are used for many different resource inventory, management, and tracking purposes within DNR, and other agencies and organizations. The benefits of using GPS tools to collect feature locations and attributes in the field include:

- Capture more accurate field data for mapping and analyses. Assuming you use recommended data collection and processing techniques, GPS data can be accurate to 5 meters or less. At this time, no other data collection tool or method commonly used within DNR produces data with this level of positional accuracy. GPS locations are also recorded in the field, which means that you can collect other on-site information at the same time!

- Collect vertical data. Survey grade GPS tools are used to collect highly accurate vertical locations of features. You can also use mapping/resource grade GPS receivers to collect vertical data, but these data are generally 2-3 times less accurate than horizontal data collected with the same receiver.

- Locate features not visible on maps, photographs, or other "base" sources. You can use GPS to collect the locations of features (e.g., trail signs) that are too small be visible on a standard map, aerial photograph, or other base source. GPS can also be used to locate features that are hidden by obstacles (e.g., trees, buildings) or that were built (e.g., roads) after a map, photograph, or other base source was created/compiled.

- Increase the efficiency of field data collection. In some cases, GPS can replace some traditional field mapping tools/techniques, such as those that rely on compasses and paper maps. GPS receivers with real-time capabilities capture highly accurate x-y coordinates for point features almost instantaneously. You can create and load customized data dictionaries (i.e., menus or lists of feature attributes) on some GPS receivers to simplify and standardize collection of these data. Depending on the particular project, use of GPS tools may reduce the amount of equipment and staff needed in the field. Finally, you can collect GPS data by walking or mounting a GPS antenna on the roof of a vehicle and driving to, along, or around a feature.

- Navigate to a site or feature of interest. You can use GPS tools to navigate to a site by entering its *x-y* coordinates (e.g., Latitude/Longitude), even if you have never been there before! Several DNR programs use this GPS functionality, for example, to return to the same sampling point over time, and to coordinate law enforcement surveillance air patrols with officers on the ground or in boats.

5. OTHER DATA COLLECTION TOOLS USED IN DNR

Other data collection tools (i.e., non-GPS) commonly used in DNR are listed below. Please refer to the companion document, ***Location Matters: Locational Data Basics***, for more information about these tools and techniques.

- Digitizing on-table from paper or film media. The locations and attributes of many real-world features can be collected on a "digitizing table" from maps, photographs, or other base sources. The accuracy of these data is primarily dependent on the scale of the source.

- Digitizing on-screen from digital data. Many DNR staff digitize the locations of features on their computer screens using scanned topographic maps, specifically 1:24,000-scale digital raster graphics (DRGs), or digital orthophotos (DOPs) as the backdrop.

  - DRGs are digital versions of U.S. Geological Survey (USGS) 7.5-minute paper quadrangle maps and are available statewide. Information about DRGs available within DNR can be found on the Intranet at: http://intranet.dnr.state.wi.us/int/at/et/GEO/drg.html.

  - DOP coverage for Wisconsin is not yet complete. But, DOPs are often more up-to-date than other sources, and have higher resolution and greater potential accuracy. A map of DOPs available in DNR can be accessed at: http://intranet/int/at/ET/GEO/dops/mrsid_stat.html. One common problem encountered while using DOPs is that landmarks may be difficult to find, especially in areas of heavy vegetation.

- Geo-coding. Street address, management unit identifier, and Public Land Survey System (PLSS) description (e.g., T.12N R.13E NW of NE Section 23) are examples of "relative referencing systems". These feature locations are considered "relative" because all features within the same "unit" (e.g., PLSS ¼-¼-section) are assigned the same identifier, or geo-code, even though they may actually be located anywhere within that unit. Geo-coded feature locations are usually less accurate than locations collected using other tools/methods, with accuracy primarily dependent on the size and configuration of the relative referencing system unit. Information about DNR's address and PLSS geo-coding tools is available on the ***Location Matters*** homepage: http://intranet.dnr.state.wi.us/int/at/et/GEO/.

- Other "in-field" and "in-office" data collection tools and techniques. Other data collection tools and techniques are used to meet specific program needs and requirements.

II. GPS RECEIVER GRADES

A civilian GPS receiver is generally categorized as (1) recreational grade, (2) mapping/resource grade, or (3) survey grade, based on its functionality. The characteristics of each of these GPS "grades" are briefly described below, and then listed in a table for easier comparison.

1. RECREATIONAL GRADE GPS

Recreational grade GPS receivers are the least expensive and the simplest to use, because they have less functionality (and less associated software and hardware!) than the other grades. As the name implies, these "handheld" GPS receivers are intended primarily for recreational purposes. Within DNR, recreational grade GPS receivers have been used for a few specific navigation and surveillance purposes because they can quickly collect the *x-y* coordinates of point features, and can be used to pre-plan routes and/or navigate to specific locations using waypoints. They are not, however, recommended for most data field collection or mapping activities within DNR. Some of the more expensive recreational grade receivers also come with a radio receiver for real-time differential correction of data.

2. MAPPING/RESOURCE GRADE GPS

It is recommended that DNR programs use a mapping/resource grade GPS to collect data that will or may be used in a geographic information system (GIS) for mapping or analysis purposes. Mapping/resource GPS tools capture data of higher positional accuracy than recreational units, and all have post-processing differential correction capabilities. Unlike recreational GPS, these receivers also collect locations for features represented as points (e.g., sample point), lines (e.g., trail), ***and*** areas (e.g., field boundary). The amount of mapping/resource GPS equipment required in the field ranges from "handheld" to "backpack" systems. The more expensive mapping/resource grade GPS units are designed to (1) collect and store large volumes of data, (2) be used in extreme environmental conditions (i.e., "ruggedized"), and/or (3) perform real-time differential correction of data.

3. SURVEY GRADE GPS

Survey grade GPS tools are only used for very specialized surveying-related activities. For example, professional land surveyors use these GPS tools for geodetic surveys, and to measure elevations. These systems produce data of the highest horizontal and vertical positional accuracy, but are very expensive and complex (some require a truck to carry all the equipment!). The use of a survey grade system requires specialized training, and one or more dedicated program staff to oversee its use and maintenance. Survey grade GPS data are always differentially corrected using real-time techniques, but may also be post-processed to increase their accuracy even more!

4. COMPARING GPS RECEIVER GRADES

RECREATIONAL GRADE	MAPPING/RESOURCE GRADE	SURVEY GRADE
Primary Uses		
• Navigation; hunting; fishing; camping; backpacking; hiking	• resource mapping; navigation	• resource mapping; site mapping; surveying; navigation (stakeout); vertical measurement
Horizontal Data Accuracy		
• 10 to 20 m *(no correction)* • 5 m *(real-time correction only)*	• 10 to 20 m *(no correction)* • 0.5 to 5 m *(real-time or post-processing correction)*	• <2 cm *(real-time correction)* • additional post-processing may improve accuracy to <1 cm
Vertical Data Accuracy		
• not used to collect vertical data	• 2 to 15 m *(2 to 3 times less accurate than horizontal data)*	• <2 cm *(real-time correction)* • additional post-processing may improve accuracy to <1 cm
Differential Correction Options		
• no post-processing capabilities • real-time some receivers	• post-processing all receivers • real-time some receivers	• real-time all receivers • additional post-processing to improve accuracy all receivers
Type of Features Collected		
• points only	• points, lines and areas	• points, lines and areas *(primarily used for point data!)*
Option to Load Custom Data Dictionary with Feature Attributes		
• unavailable at this time	• all receivers	• all receivers
Option to Load Custom Coordinate Systems, Projections, Datums/Spheroids		
• some receivers	• all receivers	• all receivers
Option to Navigation Using Waypoints		
• all receivers	• all receivers	• not practical for navigation
Time Required to "Lock on" to Satellites before Collecting Data		
• 5 to 10 minutes	• 2 to 5 minutes	• 2 to 10 minutes
Number of Data Points Collected/Stored before Download Required		
• <1,000	• 10,000 to 50,000	• >50,000
Training Requirements		
• minimal	• moderate	• advanced
Cost		
• $200 to $500	• $2,500 to $12,000	• $35,000 to $75,000

III. GPS ACCURACY CONSIDERATIONS

You can ensure that the quality of your data is high by understanding the sources of error that can affect GPS data…

- Conditions in the ionosphere and atmosphere (e.g., solar flares)
- Selective availability (disabled by DOD on May 1, 2000)
- Number of available satellites and their geometry and health
- GPS receiver default settings (e.g., PDOP, mask angle)
- Signal interference (e.g., multipath errors) by obstacles such as buildings and trees
- Number of data points collected for a feature
- How and if data are differentially corrected
- Base station used for differential correction

…and by using appropriate data collection and processing techniques to minimize these sources of error. Obviously, users cannot control some of the conditions (e.g., solar flares, selective availability, satellite characteristics) under which GPS data are collected. However, when selecting appropriate GPS tools for your project, you must consider that some receivers allow you to (1) set default values, and (2) perform differential correction to minimize these sources of error and make your GPS data as accurate as possible.

1. **DEFAULT SETTINGS THAT AFFECT GPS DATA ACCURACY**

Many GPS receivers let you set certain defaults that can affect the accuracy of your data. If you are investigating the use of GPS tools, you should understand the basic principles described below, and consider them when selecting a receiver for a specific project.

A. Position Dilution of Precision (PDOP)

Most GPS receivers allow you to set a default Position Dilution of Precision (PDOP). The PDOP is one of the most important parameters in GPS data collection, and indicates which satellites are available, and the geometry among them. The principle behind PDOP is that GPS data are more accurate if (1) the satellites are evenly distributed in all four quadrants above the receiver and (2) the satellites are the same distance above the horizon. In general, the lower the PDOP value, the greater the accuracy of the position data you are collecting. GPS receivers automatically calculate the PDOP and, depending on the number of channels available, may select the satellites that produce the best PDOP at any given time. <u>We recommend that you set your GPS receiver to stop collecting data when the PDOP is over 6</u>.

B. Elevation Mask Angle

As mentioned above, the distance of satellites above the horizon is used to calculate PDOP. Most GPS receivers let you set the "elevation mask angle" to ensure that the GPS receiver only tracks and uses satellites that are positioned a specified distance above the horizon. Be aware that you must consider local topography and obstacles blocking the horizon, such as vegetation or buildings, when determining an appropriate elevation mask angle. <u>We recommend that you set the elevation mask angle on your GPS receiver to 15° or greater</u>.

C. Number of Points Collected Versus Data Collection Rate

The number of *x-y* coordinate readings you collect for a feature directly affects the accuracy of GPS data. You decide, based on your program's data accuracy requirements, how many readings (or how long) the GPS receiver will collect data to represent a feature. But beware…there is a direct **relationship between the number of points you collect and the rate at which you collect them!** You must carefully consider the balance between these two factors, especially when using GPS tools to locate line and area features, and set a default data collection rate (e.g., one per second, one every five seconds) that supports your program's data accuracy requirements.

In general, the more readings you record, the more accurate a feature's location will be – **except** GPS data accuracy does not significantly improve after a "threshold" number of points are collected. Please refer to the companion document, *DNR GPS Accuracy Report*, for recommendations about the number of points to collect with various recreational and mapping/resource grade GPS receivers commonly used in DNR. These principles also affect how fast you may walk or drive when collecting data for line and area features.

D. Offsets to Address Multipath Errors

Multipath errors occur when satellite signals bounce off nearby obstacles (e.g., buildings, vegetation) before being received by the rover GPS unit. This interference affects signal travel times (which are used in position calculations), and may result in false feature locations. In some cases, obstacles can completely block satellite signals from reaching the rover receiver. Some GPS receivers allow you to set offsets to address potential multipath errors, especially in areas with heavy tree canopy or in urban settings.

You should refer to the manufacturer's documentation for information about the offset capabilities of a specific GPS receiver. In cases where trees, especially coniferous stands, are blocking GPS signals, you may need to optimize the timing of your data collection to coincide with the greatest number of satellites above the 15° elevation mask angle. In the case of deciduous tree canopy, you may also want to consider collecting data in "leaf-off" conditions (i.e., in spring or fall).

2. DIFFERENTIAL CORRECTION TO IMPROVE GPS DATA ACCURACY

Differential correction removes most types of error from GPS data, and can occur back in the office (post-processing) or as you are collecting data in the field (real-time). Post-processing and real-time differential correction techniques produce similar GPS data accuracy results. Both work by comparing satellite signals received by the rover receiver with those received by a base station, which is fixed over a highly accurate, surveyed point. Base station correction values are calculated and then applied to the rover data to increase their accuracy to 5 meters or less, depending on the GPS receiver grade.

Both post-processing and real-time differential correction require that the base station and rover receiver are able to record data from the exact same satellites! In addition, the base station should be within 100 miles of the field data collection site. When a base station is more than 100 miles from the rover receiver, the curvature of the earth prevents both receivers from recording data from the same satellites.

If your program is considering differential correction of GPS data, you must decide which method will best support your business needs, and if your program resources are adequate to support the selected tool/technique. The major differences between these differential correction methods are related to (1) costs of equipment versus processing time and (2) instantaneous versus delayed access to feature location data. The characteristics of post-processing and real-time differential processing are described in more detail below.

A. Post-Processing Differential Correction

Post-processing can dramatically reduce errors in data collected with a mapping/resource grade GPS receiver. Post-processing is not available for recreational grade units at this time. This type of differential correction occurs back in the office, after you have downloaded raw GPS data from the rover receiver on to a computer. Special software (specific to the GPS receiver!) is used to apply correction values calculated from base station data to the rover data.

In most cases, you can download free base station data from an Internet site operated by the National Geodetic Survey (http://www.ngs.noaa.gov/CORS/). A list of other community base stations is available on Trimble's website (http://www.trimble.com/gis/cbs/). You can also set up a temporary base station for a specific project, but this requires special training.

GPS equipment with post-processing functionality is generally less expensive than systems with real-time functionality, because less hardware is required (i.e., there is no need for a real-time beacon receiver). Post-processing, however, is much more time consuming than real-time correction, which takes place instantaneously in the field. So…you must consider whether the cost of staff time to post-process data is more or less than the cost difference between a post-processing and real-time system!

B. Real-time Differential Correction

Some recreational and mapping/resource grade GPS receivers have real-time differential correction functionality (also known as Differential GPS - or DGPS). Survey grade GPS generally uses real-time differential correction. This type of correction occurs in the field, and requires another piece of equipment to receive correction values from a GPS base station via radio signals, and automatically apply these data to adjust GPS rover data as they are being collected. Three types of units are used to receive base station correction data:

- external real-time radio link receiver (e.g., "beacon-on-the-belt")
- real-time radio link receiver built into the GPS receiver
- direct satellite link built into the GPS receiver (i.e., correction data are transmitted from the base station up to the satellite and then back down to the rover receiver)

It is important that the base station transmitting the radio signals carrying the correction values be within 100 miles of the field data collection site. A map of Continuously Operating Reference Stations (CORS) maintained by the National Geodetic Survey can be found at http://www.ngs.noaa.gov/CORS/. Radio signals carrying correction data can be received from base stations more than 100 miles from the field data collection site, but results are inconsistent and use of these correction data are not recommended for real-time differential correction. For example, a small portion of north central Wisconsin is not within 100 miles of a CORS site, and post-processing differential correction is recommended for data collected in this area. Differential correction is also recommended when base station radio signals are blocked by terrain (e.g., common in the "driftless" area of southwest Wisconsin).

Systems with a built-in satellite link provide real-time capabilities anywhere in the world. Depending on your program's needs, a GPS receiver with real-time differential correction may also help you navigate to a site or feature more accurately and quickly.

IV. OTHER GPS CHARACTERISTICS TO CONSIDER

In addition to your ability to set defaults and differentially correct data using a specific GPS receiver, you must also consider the following receiver characteristics and conditions before finally choosing the right GPS receiver for your project!

1. NUMBER OF CHANNELS

GPS receivers track the signals from satellites via "channels", with the signals from one satellite occupying one channel on the receiver. So…a 3-channel GPS receiver tracks the signals from up to three satellites at one time, while a 12-channel receiver tracks the signals from up to twelve satellites at one time. Technically, a GPS receiver only needs three channels (and satellites) to collect horizontal data (and four channels to collect vertical data). However – *the more channels a receiver has, the more likely that it will continue uninterrupted collection of data if the parameters (e.g., PDOP) of one of the satellites fall out of optimal range!* A GPS receiver with six or more channels only collects feature location data using the "best" three or four channels, and keeps seeking out other satellites with more optimal parameters. Therefore, we recommend that GPS receivers used within DNR have the **ability to track at least 6 channels**.

2. MEMORY

The number of data points that a GPS receiver can collect and store (before you need to download the data to a computer) differs greatly between recreational and mapping/resource systems. Recreational grade receivers can only collect and store data for less than 1,000 points – and users do not usually downloaded these data for further processing or analysis. Therefore, memory requirements of recreational grade receivers are of less concern. You must, however, consider how the field conditions of your project may influence the memory requirements of your mapping/resource GPS receiver.

- **How many features will be located?**
  More features may require more memory to minimize the number of data downloads you need to perform.

- **How large are the line or area features to be located?**
  Long linear features (e.g., trails) or polygon features with very large areas (e.g., forest stand boundaries) may require more memory to store all collected data. In addition, a GPS receiver that lets you open and append data to existing files will minimize the number of total files you need to create and compile for one feature.

- **How remote are the features to be located?**
  Remote features may require more memory to minimize the number of trips you need to make into the field, or into the office to download data (e.g., if no laptop is available).

- **Will a customized data dictionary be loaded on the receiver?**
  The use of data dictionaries is highly recommended, and they take up memory!

- **What are your data accuracy requirements?**
  More memory may be needed to capture and store the larger volume of data needed to support higher data accuracy requirements.

We recommend that your mapping/resource grade GPS receiver have a **minimum 250Kb** of memory. This amount of memory allows loading of a custom data dictionary and collection of approximately 9,000 points. At a rate of one point per second, for example, a receiver with 250Kb of memory can be expected to collect data continuously for 2-3 hours.

3. GPS POWER SOURCE

GPS receivers run on electricity, so it is important to have a good battery supply available in the field. Most recreational grade receivers run adequately on 1.5-volt or other battery recommended by the manufacturer. We recommend that you consider mapping/resource grade systems that use a **12-volt, rechargeable battery** as the main source of power. These 12-volt batteries will last all day, and can be recharged at night.

4. DATA DICTIONARY OF FEATURE ATTRIBUTES & RECEIVER KEYPAD

Recording descriptive data about features in the field, while you are locating those same features, can increase the efficiency and effectiveness of your data collection efforts. For example, noting feature attributes on-site can reduce confusion and mislabeling back in the office.

A. Loading a Customized Data Dictionary of Feature Attributes

Most mapping/resource grade GPS receivers come with a software application that lets you create a customized attribute data dictionary (or menu) on your computer, and then load it on your GPS receiver. A data dictionary lists standard feature attributes (i.e., data elements) to be collected and the fill requirements, default values, and valid codes/values for each. They can also be used to automatically record data collection time and date. A data dictionary may be simple or very complex (e.g., with many nested menus), depending on the particular project. We recommend that you **use a GPS data dictionary whenever possible** to simplify data collection and standardize field data.

B. GPS Receiver Keyboard/Keypad Options

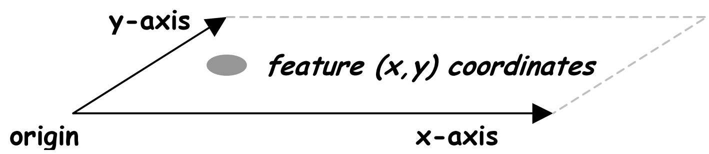
If you intend to use a data dictionary, you must also consider the GPS receiver's data entry keyboard or keypad option(s). For example, if you need to type in a lot of alphanumeric characters, you may want to consider using a GPS receiver with an alphanumeric keypad, rather than one that requires you to use arrow keys to scroll through letters, numbers, and symbols.

5. EXPORTING GPS DATA IN A GIS FORMAT

Data collected using a mapping/resource grade GPS is managed, analyzed, and displayed using GIS tools. In order for your GPS data to integrate easily with DNR's standard GIS software, we recommend that you use a GPS that includes software to convert your field data into **ArcView shapefile format** or **ArcInfo coverage format**. Some systems export GPS data in DXF or other formats, which may be imported into ArcView or ArcInfo with some effort. However, processing and integrating these data will require additional program resources and time.

6. CUSTOMIZED COORDINATE SYSTEMS, PROJECTIONS, DATUMS/SPHEROIDS

A coordinate system is a mathematically derived framework of *x-y* coordinates. Each coordinate system is defined by its unique combination of (1) *x-axis* and *y- axis* origins, (2) measurement unit, (3) reference datum or spheroid, and (4) map projection (if applicable). Please refer to the document, *Wisconsin Coordinate Systems* (Wisconsin State Cartographer's Office. 1995), for more information about coordinate systems and their components.



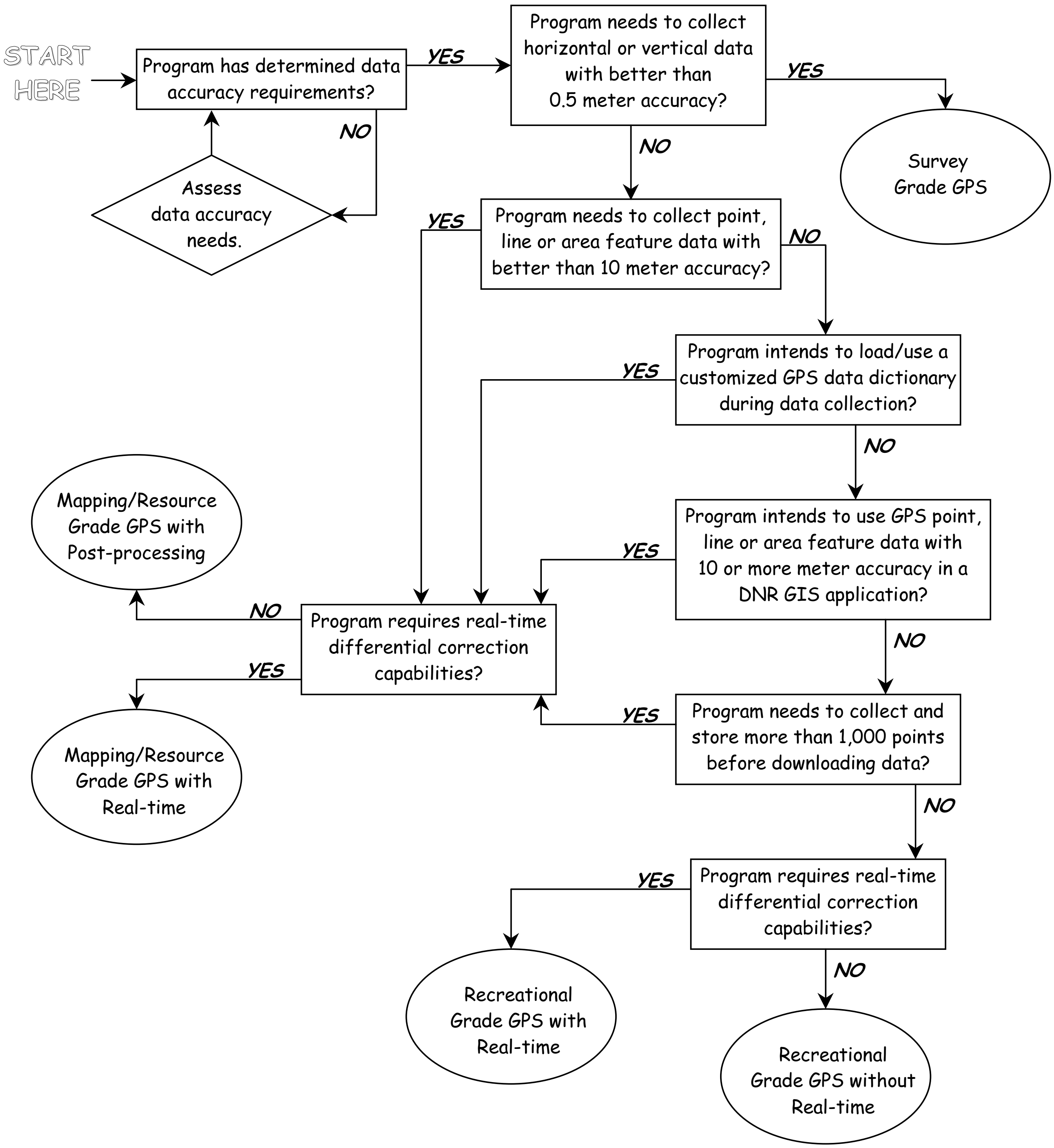
Most GPS receivers let you set a default coordinate system and datum or spheroid for capturing field data. Latitude/longitude (expressed in decimal degrees or degrees/minutes/seconds) and Universal Transverse Mercator (UTM – expressed in meters) are among the more common coordinate systems for collecting GPS data. We recommend that, whenever possible, you collect GPS data in Latitude/Longitude coordinates, expressed in decimal degrees, and referenced to the World Geodetic System of 1984 (WGS84) spheroid. (Latitude/Longitude measurements are referenced to a spheroid rather than a datum.) Please refer to DNR's ***Locational Data Standards*** (at http://intranet.dnr.state.wi.us/int/at/et/geo/location/loc_stds.html) for information about coordinate systems and procedures for properly documenting your data collection activities.

As mentioned above, mapping/resource grade GPS data are maintained, analyzed and displayed using standard GIS tools. To simplify data use and integration, all of DNR's GIS framework data layers are stored and managed in the Wisconsin Transverse Mercator coordinate system referenced to the 1991 adjustment to the North American Datum of 1983 (GRS80 spheroid). This referencing system is known as WTM91. This means that GPS data must be converted to WTM91 for use in DNR's GIS applications.

Projecting data between coordinate systems is a complex process, and can result in significant errors if not done correctly. The Enterprise Data Management Section's "projection service" can help programs convert their data (http://intranet.dnr.state.wi.us/int/at/et/GEO/prj_srvc.htm). We are also currently testing several algorithms to be loaded on mapping/resource grade GPS receivers for projecting and exporting data directly into WTM91.

V. GPS RECEIVER GRADE "DECISION TREE"

This "decision tree" is intended to help a DNR program select an appropriate receiver grade for its particular GPS data collection project. This is only a general guide, however, and you must also consider several other factors (listed in this document) before making your final choice!



VI. MINIMUM REQUIREMENTS FOR MAPPING/RESOURCE GRADE GPS

Based on the previous discussion, the following minimum configuration is recommended for mapping/resource grade (and recreational grade where specifically noted) GPS receivers used within DNR. Recommendations for survey grade systems are not included because they are used for very specialized projects, which have very specific functionality requirements.

Differential Correction	post-processing minimum; real-time for some business needs
Number of Channels	6 channels minimum
Memory	250Kb minimum
Power Source	12-volt rechargeable battery + recharger and extra battery
Feature Representation	records data for points, lines and areas
Customized Data Dictionary	can create and load custom data dictionaries
Export Data in GIS Format	ArcView shapefile format or ArcInfo coverage format
Customize Projections & Datums	can load parameters for custom projections and datums

VII. FUTURE GPS TRENDS

Like all technology, GPS tools and techniques are constantly evolving and advancing. As staff resources permit, we will continue to research GPS trends, such as those described below, and provide guidance to DNR staff about them.

<u>Combination GPS Receiver/Cellular Phone</u>. These units combine a recreational grade GPS receiver (usually without real-time differential correction capabilities) and a cellular phone in one casing. In some cases, the cellular phone is used to send GPS coordinates collected in the field to a computer (loaded with special software) in the home office.

<u>ArcPad for "Field" GIS</u>. We are designing a study to investigate the use of ESRI's ArcPad software for field GIS activities (i.e., data collection and mapping). A GPS receiver can be connected to a palmtop computer loaded with ArcPad, and the GPS locations of features mapped on a DNR GIS framework layer (e.g., hydrography, digital orthophoto) that is also been loaded on the palmtop. Data collected in the field are automatically downloaded in ArcView shapefile format for use in other GIS applications back in the office.

<u>Customizing GPS Receivers to Export Data in Specific Coordinate Systems/Datums/Spheroids</u>. We are currently testing several algorithms (to be loaded on specific GPS receivers) that allow users to export GPS data directly as WTM91 coordinates. This process can greatly reduce the amount of time spent projecting data using traditional ArcInfo methods.

<u>Mobile Resource Tracking Systems</u>. Inquiries from DNR programs about GPS-based mobile resource tracking systems continue to increase. These systems are highly specialized and should be assessed on a case-by-case basis. However, we hope to gather information about the types of systems used by DNR programs in order to provide other prospective users with adequate guidance and contacts.

Improvements to Recreational Grade Receivers. We will continue to investigate improvements in the functionality of recreational grade GPS receivers, and provide guidance about their appropriate use for data collection and mapping activities within DNR.

VIII. EXTERNAL SOURCES OF GPS INFORMATION

The following Internet sites provide useful information about GPS principles and receivers, as well as links to other helpful GPS websites.

- Wisconsin State Cartographers Office – Global Positioning Systems: http://feature.geography.wisc.edu/sco/sco.html
- National Geodetic Survey – Continuously Operating Reference Stations (CORS): http://www.ngs.noaa.gov/CORS/
- The Geographer's Craft – Global Positioning System Overview: http://www.colorado.edu/geography/gcraft/notes/gps/gps_f.html
- U.S. Forest Service – GPS Information Page: http://www.fs.fed.us/database/gps/welcome.htm
- Trimble – All About GPS: http://www.trimble.com/gps/howgps/gpsfram1.htm
- Garmin – About GPS: http://www.garmin.com/aboutGPS/
- Ashtech (Magellan) – About GPS: http://www.ashtech.com/

IX. STANDARD GPS DATA COLLECTION METHOD CODES

DNR assigns the following "collection method" codes to data captured using GPS tools. Please refer to DNR's ***Locational Data Standards*** for more information about these and other related standards (http://intranet.dnr.state.wi.us/int/at/et/geo/location/loc_stds.html).

CODE	DATA COLLECTED USING…
GPS001	Survey grade receiver stationary during data collection.
GPS002	Survey grade receiver moves during data collection.
GPS003	Mapping/resource grade receiver with real-time differential correction.
GPS004	Mapping/resource grade receiver with post-processing differential correction.
GPS005	Recreational grade receiver with real-time differential correction.
GPS006	Mapping/resource or recreational grade receiver with no differential correction and selective availability off.*
GPS007	Mapping/resource or recreational grade receiver with no differential correction and selective availability on.
GPS008	GPS receiver grade and/or differential correction procedures unknown.

*** DOD disabled selective availability at midnight on 5/1/00. Applies to data collected after this date.**

X. GLOSSARY OF GPS TERMS

Accuracy: The closeness of results of observations, computations or estimates to the true values or the values accepted as being true. (United States Geological Survey. 1998)

Attribute: A defined characteristic of a real-world feature.

Base Station: A GPS receiver (and associated equipment) set up over a highly accurate, surveyed point. A base station may be permanent (e.g., Continuously Operating Reference Stations – CORS) or temporary (i.e., set up for a particular project). Data from the base station is used to correct errors in rover data, using either post-processing or real-time techniques.

Channel: A channel of a GPS receiver consists of the circuitry necessary to tune the signal from a single GPS satellite. (Hurn, J. 1989)

Continuously Operating Reference Station (CORS): A network of continuously operating base stations, maintained by the National Geodetic Survey, that provide GPS correction data throughout the United States and its territories. See website at http://www.ngs.noaa.gov/CORS/.

Coordinates: Pairs of numbers expressing horizontal distances along orthogonal axes. (U.S. Geological Survey, 1998). ***Note:*** Refers to *x-y* coordinates.

Data Dictionary: A menu of standard feature attributes (i.e., data elements) loaded on a GPS receiver and used to simplify and standardize data collection in the field. The data dictionary also defines the fill requirements, default values, and valid codes/values for each attribute.

Datum: A mathematically defined reference surface used to represent the size and shape of the Earth. A horizontal datum is defined by its ellipsoid, latitude and longitude orientation, and a physical origin. (Wisconsin State Cartographer's Office, 1995). ***Note:*** Different datums are used for horizontal and vertical data.

Differential Correction: A mathematical process for removing most types of error from GPS data by comparing measurements from two GPS receivers (i.e., rover and base station) tracking signals from the same satellites. Differential correction may occur after data have been collected (see ***Post-Processing Differential Correction***) or as data are being collected in the field (see ***Real-time Differential Correction***).

Differential Global Positioning System (DGPS): A GPS with real-time differential correction capabilities.

Elevation: The perpendicular distance of a feature above or below a vertical datum, as defined in Federal Information Processing Standard 70-1. (modified from U.S. Geological Survey, 1998). ***Note:*** "Altitude" is often used to describe the distance of a feature above a vertical datum, while "depth" refers to distance of a feature below a vertical datum.

Feature: A natural or man-made object, formation, or boundary of Earth.

Geographic Information System: A system of software, hardware, data, and people used to collect, analyze, manage, and display locational and attribute data about features.

Ionosphere: The band of charged particles 80 to 120 miles above the Earth's surface. (Hurn, 1989).

Multipath Error: Errors caused by the interference of a signal that has reached the receiver antenna by two or more different paths. Usually caused by one path being bounced or reflected. (Hurn, 1989).

Post-Processing Differential Correction: Differential correction that uses special software for comparing base station and rover data to improve the accuracy of rover data ***after they are collected in the field***.

Position Dilution of Precision (PDOP): A mathematical factor, automatically calculated by GPS receivers, that indicates which satellites are available, and the geometry among them.

Projection: The method used to transform and portray the curved surface of the Earth as a flat (map) surface. Although there are theoretically an infinite number of possible projections, a relatively small number are commonly used. Different projection systems have differing amounts and patterns of distortion. (Wisconsin State Cartographer's Office, 1995)

Real-time Differential Correction: Differential correction that requires use of a radio receiver to capture and apply correction data from a base station to improve the accuracy of rover data ***as they are being collected in the field***.

Receiver Grade: The type (i.e., recreational, mapping/resource, or survey) of GPS receiver, based on its functionality.

Rover Receiver: A GPS receiver (and associated equipment) used in the field to collect feature location and attribute data. Some rover receivers also have a radio receiver for real-time differential correction.

Ruggedized: Equipment that has been reinforced for use in extreme (e.g., temperature) field conditions.

Selective Availability (SA): Intentional degradation of GPS satellite signals by the Department of Defense (DOD). SA was disabled (i.e., turned off) on midnight, 5/1/2000 in an effort to benefit many civilian activities such as transportation, navigation, emergency response, recreation, wildlife tracking, and resource management. When activated, SA was usually the largest source of error affecting GPS data, limiting accuracy to about ±100 meters without differential correction.

Spheroid: An ellipsoid that approximates a sphere is commonly referred to as a spheroid. An ellipsoid is a mathematical surface (an ellipse rotated around the Earth's polar axis) which provides a convenient model of the size and shape of the Earth. The ellipsoid is chosen to best meet the needs of a particular geodetic datum system design. (Wisconsin State Cartographer's Office, 1995).

Waypoint: A point with known *x-y* coordinates used for GPS navigation purposes.

XI. REFERENCES

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Wisconsin State Cartographer's Office. 1995. *Wisconsin coordinate systems*. Madison, Wisconsin: Board of Regents of the University of Wisconsin System. 💻 document available for viewing or purchase at: http://feature.geography.wisc.edu/sco/sco.html